



*For conversion of SI metric units to U.S./British customary units of measurement consult ASTM Standard E380, Metric Practice Guide, published by the American Society for Testing and Materials, 1916 Race St., Philadelphia, Pa. 19103.*

*COVER: Cross section of a floating vegetation mat  
- that has developed over extensive areas in  
- groundwater-discharge wetlands in the  
- Tanana Flats.*



**U.S. Army Corps  
of Engineers**  
Cold Regions Research &  
Engineering Laboratory

## Groundwater-Discharge Wetlands in the Tanana Flats, Interior Alaska

Charles H. Racine and James C. Walters

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## **PREFACE**

This report was prepared by Dr. Charles H. Racine, Research Biologist, Geological Sciences Branch, Research Division, U.S. Army Cold Regions Research and Engineering Laboratory, and Dr. James C. Walters, Department of Earth Science, University of Northern Iowa, Cedar Falls, Iowa. The report is based on a study of the impacts of airboats on the Tanana Flats area of Ft. Wainwright, Alaska, funded by the U.S. Army 6th Infantry Division (Light), Department of Engineering and Housing, Ft. Richardson, Alaska. The authors thank 'unior Kerns, wildlife biologist, Ft. Wainwright, Alaska, and Dr. Daniel Lawson and Dr. Steven Arcone, both of CRREL, for reviewing the manuscript.

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CHARLES H. RACINE AND JAMES C. WALTERS

## INTRODUCTION

The Tanana Flats is part of the Tanana Lowlands, a large interior river basin in east-central Alaska (Fig. 1). Other such basins in Alaska include the Yukon Flats and the Kuskokwim Flats. These are associated with large rivers and contain extensive wetlands that constitute important waterfowl breeding areas (Lensink and Derksen 1986). Although wetlands are well developed in these flat and poorly drained basins, the type of wetlands vegetation is by no means similar, and the geomorphology, permafrost and hydrologic conditions responsible for their development are poorly known. Ford and Bedford (1987) stated that hydrologic information is virtually absent for the alluvial wetlands associated with most large rivers in Alaska.

Although the Tanana River basin is one of the most intensively studied areas in Alaska because of its proximity to the University of Alaska at Fairbanks, most research has concentrated on the uplands north of the river (Haugen et al. 1982) or on the flood plain processes near the river (Van Cleve et al. 1986). These areas are environmentally quite different from the Tanana Flats south of the Tanana River, which are presently not influenced by riverine processes.

A few terrain studies have been conducted in the Tanana Flats by CRREL in conjunction with the use of the area for military training by Ft. Wainwright. These include a study of the effects of winter military operations on the terrain (Abele et al. 1978), a thermal infrared survey of winter trails (Collins and Haugen 1990) and a terrain study of the Blair Lakes training area near the southern edge of the Tanana Flats (Doe et al. 1985).

During a 1989 study of the impacts of airboats on wetlands in the Tanana Flats we discovered that the airboats use an extensive system of wetlands. These wetlands consist of floating vegetation mats that appear to be unique and previously undescribed in Alaska. This

study attempts to describe and understand the origin of these wetlands and their areal extent in relation to vegetation, permafrost and hydrology.

## THE STUDY AREA

The study area, where airboat access and use has increased dramatically over the past decade, is located just south of Fairbanks in the northwest corner of the Tanana Flats between Salchaket Slough, the Tanana River, Clear Creek Butte and Willow Creek (Fig. 1). This area slopes gently to the northwest from an elevation of 142 m (475 ft) at the base of Clear Creek Butte to 120 m (400 ft) at the Tanana River. The average gradient in this portion of the flats is slightly more than 1 m/km. Very poorly developed stream and drainage channels run from southeast to northwest through the flats. Clear Creek and Salchaket Slough at the northern edge of the study area and Willow Creek at the southern edge are the only continuous drainages (Fig. 1).

The Tanana Flats makes up the east-central portion of the middle Tanana Lowland, a broad depression between the Alaska Range on the south and the Yukon-Tanana Upland on the north and stretching from near Big Delta on the east to near Manley Hot Springs on the west (Péwé 1975). This depression is a structural basin, and much of its bedrock floor is below sea level. As the trough was subsiding, it filled with accumulations of fluvial and glaciofluvial sediments shed from the rising Alaska Range on the south. Deposition of this material formed a broad slope of coalesced alluvial fans, which pushed the Tanana River northward against the Yukon-Tanana Upland. The total thickness of these deposits is unknown, but they must be on the order of several hundred meters thick, as indicated by a well approximately 75 km west of the study area that penetrated over 600 m of gravel (Anderson 1970). Quaternary-age deposits at the surface are known to be 91–230 m thick

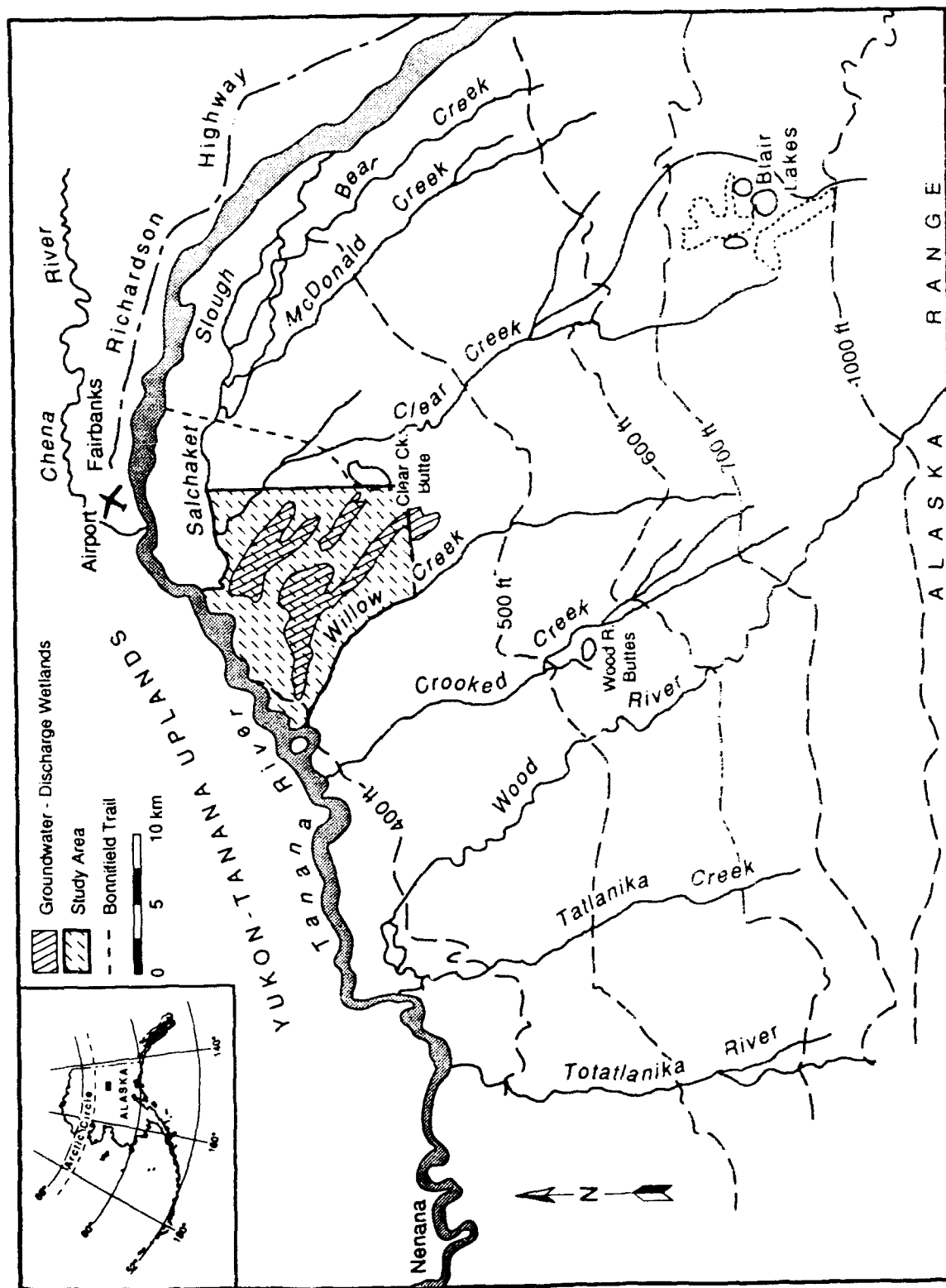


Figure 1. Tanana Flats area south of the Tanana River in interior Alaska, showing where extensive groundwater discharge wetlands are located.

(Péwé and Reger 1983). This wedge of sediments apparently buries a fairly rugged topography, the hill-tops of which rise above the plain in places as small, isolated, bedrock knobs. The sediments grade from coarse, well-drained gravels in the upper portions of the fans flanking the Alaska Range to poorly drained, fine-grained sediments at the lower reaches of the coalesced fans where the Tanana Flats is found.

The thick unconsolidated deposits filling the middle Tanana Lowland document a long and complex record of alternating cycles of silt and gravel deposition and erosion along with the formation and destruction of permafrost (Péwé and Reger 1983). Climatic fluctuations during the Quaternary caused glacial expansion and recession in the Alaska Range, which in turn resulted in episodes of deposition and erosion in the basin. The geologic history of the basin is an important controlling factor in the present hydrology of the Tanana Flats. The alternating layers of frozen fine-grained sediments and unfrozen coarse sediments either prevent or permit, respectively, the movement of groundwater through the flats.

The Tanana Flats lies entirely within the discontinuous permafrost zone, and the Tanana Flats is generally considered to be underlain by frozen ground (Péwé 1975). However, there are no drillholes in the flats to confirm this, and frozen-ground features (such as ice-wedge polygons, palsas and thermokarst) are uncommon. Permafrost is probably sparsely distributed on the high, southern part of the foothills fans, where coarser sediments result in better drainage. Hopkins et al. (1955) also indicated that frozen ground is lacking in many places on the piedmont slope, especially where groundwater circulation is active and where there is the thermal influence of surface water bodies. Elsewhere, frozen ground exists within 0.5–4 m of the surface and is between 5 and 10 m thick (Hopkins et al. 1955). Permafrost is probably more widespread in the Tanana Flats at the lower slopes of the broad, coalesced fans, where fine-grained sediments occur and drainage is relatively poor. On the north side of the Tanana River in the Fairbanks area, Péwé and Reger (1983) reported that frozen ground frequently occurs as multiple layers of varying thickness. This is probably due to the variable nature of the flood plain sediments, with the sands and silts being frozen but the coarser, better-drained gravels being unfrozen. The depth to permafrost in this area varies from 0.6 to 1.2 m, and thicknesses up to 81 m exist (Péwé and Reger 1983). Permafrost conditions are probably very similar on the south side of the Tanana River in the Tanana Flats.

No wells have been drilled in the Tanana Flats or in the adjacent alluvial fans. In addition, no gauged streams exist in the area, and no water quality studies of surface

water or ground water have been carried out (Hydrographic Topographic Center 1978). Only the extreme northern portion of the Tanana Flats, from Salchaket Slough north to the Tanana River, has received any specific study; Péwé and Bell (1975) studied this area as part of an investigation of wells drilled north of the Tanana Flats in the city of Fairbanks and suburbs.

The area has a continental climate, with an extreme range between summer and winter temperatures (Péwé and Reger 1983). The mean annual temperature in Fairbanks is  $-3.28^{\circ}\text{C}$  ( $26.1^{\circ}\text{F}$ ), with a minimum recorded temperature of  $-54.4^{\circ}\text{C}$  ( $-66^{\circ}\text{F}$ ) and a maximum recorded temperature of  $37.2^{\circ}\text{C}$  ( $99^{\circ}\text{F}$ ). During the past decade, there has been a strong warming trend in interior and northern Alaska (Osterkamp 1983). Annual precipitation in Fairbanks is 297 mm (11.7 inches), most of which falls as light summer showers. The mean annual snowfall is 1692 mm (66.6 inches).

The vegetation of the flats is a complex mosaic of stunted forests (white birch, white and black spruce and tamarack), shrub scrub (willows, alder and heaths) and the open wetlands described here. This vegetation pattern is related to slight changes in topography of only 0.5 to 2 m. White birch forms pure stands on the highest, best-drained areas along streambanks. The vegetation pattern is further influenced by beaver activity and wildfire.

## METHODS

Field studies during the summer of 1989 defined the distribution and structure of wetlands being used by airboats in the northwest corner of the Tanana Flats. Twenty wetland trail sites at various locations between the Tanana River and Clear Creek Butte were visited by helicopter and airboat, and characteristics of the vegetation, water flow and water chemistry were measured. Aerial photos (both true color and color infrared) and satellite images, together with vegetation maps prepared by the U.S. Soil Conservation Service, were used to map the distribution of the wetlands described in this report.

At several wetland sites a transect from the wetlands onto the adjacent upland was established, along which a soil probe was used to determine subsurface characteristics, including soil type, presence of frozen ground, floating mat thickness and water depth. Flow rates of the surface water were measured with a hand-held flow meter. Vegetation was sampled by making species lists, measuring plant height and estimating cover for each species. At two sites all of the above-water vegetation in two  $0.2 \times 0.5\text{-m}$  ( $0.1\text{ m}^2$ ) quadrats was harvested and returned to the laboratory for drying and weighing.

Surface water samples were collected at six widely separated wetland sites. The conductivity of the water was measured at each site and again in the lab with a portable Hach conductivity meter. Surface water samples from each site were returned to the laboratory for analysis of pH and redox potential (with a Hach meter). Calcium and magnesium were determined using a Hach titration procedure that measures water hardness.

The buoyancy of the floating vegetation mat was estimated by stepping on the mat with one foot and measuring the deflection or depression of the mat relative to water level.

## RESULTS

The 20 airboat trail sites are located in an extensive network of interconnected wetlands that are bordered by slightly higher birch- or spruce-dominated forested islands and benches (Fig. 2). Because of the low-acidity and mineral-rich water (described below), the vegetation dominated by graminoids and forbs, and the absence of *Sphagnum* moss, these wetlands are best classified as "fens" (Gabriel and Talbot 1984). There are few open water areas in these fens except for occasional beaver-dammed areas and some airboat trails. These wetlands occur as both large open expanses and long linear corridors, 100–500 m wide, oriented southeast

to northwest (Fig. 2). They are most extensive in the northwest corner of the Tanana Flats between Clear Creek Butte and the Tanana River, where they make up about 13% of the total surface area (Fig. 2). Here the gradient from the Alaska Range to the Tanana River drops to less than 1 m/km.

## Vegetation

These fens consist of a highly productive floating vegetation mat made up of narrow-leaved graminoids and broad-leaved forbs (Table 1). The dominant mat-forming species include graminoid sedges (*Carex aquatilis*, *C. rostrata*), grasses (*Glyceria pulchella*, *Calamagrostis canadensis*), swamp horsetail (*Equisetum fluviatile*) and herbaceous broadleaf forbs such as buckbean (*Menyanthes trifoliata*), marsh fivefinger (*Potentilla palustris*) and water hemlock (*Cicuta mackenzieana*) (Table 1). There are occasional small stands of cattails (*Typha latifolia*). In addition to these emergents, there frequently are submerged aquatics in a shallow water layer (6–12 cm deep) that sometimes overlies the floating mat. Species here include bladderworts (*Utricularia* sp.) and duckweed (*Lemna* sp.). Mosses do not appear to contribute to the structure of these mats, and species of *Sphagnum* are conspicuously absent. Woody plant species, except for very occasional willows or gale (*Myrica gale*), are also absent from the mats.



Figure 2. Open wetland corridors composed of floating herbaceous vegetation mats over deeper water bodies. These areas are sharply bordered by slightly higher birch and spruce forests.



Table 1. Plant species composition at 20 sites. The sites nearest the Tanana River are on the left.

| Species                         | Site no. |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |
|---------------------------------|----------|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|
|                                 | 1        | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| <b>Graminoids</b>               |          |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |
| <i>Carex aquatilis</i>          | x        | - | x | x | x | - | - | x | x | x  | x  | x  | x  | -  | x  | x  | -  | x  | x  | x  |
| <i>Equisetum fluviatile</i>     | x        | - | - | x | x | - | - | - | - | x  | -  | -  | x  | x  | x  | x  | x  | -  | -  | -  |
| <i>Carex rostrata</i>           | -        | - | x | x | - | - | x | - | x | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  |
| <i>Glyceria pulchella</i>       | -        | - | - | - | x | - | - | - | - | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  |
| <i>Calamagrostis</i> sp.        | -        | - | - | - | x | - | - | - | - | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  |
| <i>Carex membranacea</i>        | -        | - | - | x | - | x | x | - | - | -  | -  | x  | -  | x  | -  | x  | -  | x  | -  | -  |
| <b>Emergent forbs</b>           |          |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |
| <i>Potentilla palustris</i>     | -        | - | x | x | x | - | - | x | x | -  | x  | x  | x  | -  | x  | x  | x  | -  | -  | x  |
| <i>Menyanthes trifoliata</i>    | x        | x | x | x | x | - | - | x | - | x  | -  | -  | x  | x  | x  | -  | x  | x  | -  | -  |
| <i>Cicuta mackenziana</i>       | -        | - | - | x | x | x | - | - | - | -  | -  | -  | -  | -  | -  | -  | -  | x  | -  | -  |
| <i>Lycopus uniflorus</i>        | -        | - | - | - | - | - | - | - | - | -  | -  | -  | x  | -  | -  | -  | -  | -  | -  | -  |
| <i>Sparanium</i> sp.            | -        | - | x | - | - | x | - | - | - | -  | -  | x  | -  | -  | -  | -  | -  | -  | -  | -  |
| <i>Triglochin palustris</i>     | -        | x | - | - | - | x | - | - | - | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  |
| <i>Callia palustris</i>         | x        | - | - | - | - | x | - | - | x | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  |
| <i>Callia palustris</i>         | -        | - | x | - | x | - | - | - | - | x  | -  | -  | x  | -  | -  | -  | -  | -  | -  | -  |
| <i>Iris setosa</i>              | -        | - | - | - | - | - | - | - | - | -  | x  | -  | -  | -  | -  | -  | -  | -  | -  | -  |
| <i>Rumex arcticus</i>           | x        | - | - | x | - | - | - | - | - | x  | -  | -  | -  | -  | -  | x  | -  | x  | -  | -  |
| <i>Ranunculus trichophyllus</i> | -        | - | - | - | - | - | - | - | - | x  | x  | -  | -  | -  | -  | -  | -  | -  | -  | -  |
| <i>Hippuris vulgaris</i>        | -        | - | x | - | - | - | - | - | - | -  | -  | -  | x  | -  | -  | -  | -  | -  | -  | -  |
| <i>Typha latifolia</i>          | -        | - | x | x | - | x | - | - | - | -  | -  | -  | -  | x  | -  | -  | -  | -  | -  | -  |
| <i>Galium</i> sp.               | -        | - | - | - | - | - | - | - | - | -  | x  | -  | -  | -  | x  | -  | -  | -  | -  | -  |
| <i>Peltastes sagittatus</i>     | -        | x | - | - | x | - | - | - | - | -  | -  | -  | -  | -  | -  | -  | -  | x  | -  | -  |
| <b>Floating and submerged</b>   |          |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |
| <b>aquatics</b>                 |          |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |
| <i>Lemna trisulca</i>           | -        | - | - | x | - | - | - | - | x | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  |
| <i>Lemna minor</i> x            | -        | - | - | x | - | - | - | - | - | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  |
| <i>Utricularia</i> sp.          | -        | - | x | - | - | - | - | - | - | -  | -  | x  | -  | -  | -  | -  | -  | -  | -  | -  |
| <i>Ceratophyllum</i>            | -        | x | - | - | - | - | - | - | - | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  |
| <i>Potamogeton</i> sp.          | -        | - | - | - | x | - | - | - | - | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  |
| <b>Shrubs</b>                   |          |   |   |   |   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |
| <i>Myrica gale</i>              | -        | - | - | - | - | x | - | x | - | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | x  |
| <i>Salix</i> sp.                | -        | - | x | - | - | x | - | x | - | x  | -  | -  | -  | -  | -  | -  | x  | -  | -  | x  |
| <i>Betula glandulosa</i>        | -        | - | - | - | - | - | - | - | - | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | x  |

\* x = present; - = absent; nd = no data.

The species composition of these mats shifts from almost pure stands of buckbean to pure stands of tall sedges. Buckbean mats are best developed in wetlands nearest the Tanana River, whereas sedge mats are more common inland toward Clear Creek Butte. The greatest diversity of species occurs on intermediate sites, with a mix of floating and submerged aquatic plants, as well as emergent graminoid sedges, grasses, horsetails and forbs. The height of the graminoid species (1–2 m) suggests that these floating mats are highly productive. Harvesting of two plots in two representative fen stands yielded above-ground standing crop live biomass values of 5,000 to 10,000 g/m<sup>2</sup>; in contrast, Luken and Billings (1983) measured biomass values of only 500–1,000 g/m<sup>2</sup> for a bog north of the Tanana River in the Yukon–Tanana uplands.

### Mat structure and buoyancy

The floating mats consist of a dense network of intertwined roots, rhizomes and organic material capable of supporting a person's weight with some deflection and compression. The mats varied in thickness between 0.7 and 0.9 m and appeared to float on the water surface. At most sites, although we were able to probe through these mats, we were unable to reach the bottom of the underlying water body. The structure of these mats appears to vary from place to place, as indicated by the variation in the depth to which we were able to deflect the mat by standing on one foot and measuring the water level on our boots. The lowest deflection values were 10 cm and the highest were 50 cm. Mats dominated by buckbean generally had the highest deflection and the highest open water cover, whereas pure sedge mats had the highest vegetation cover and the lowest deflection. At one site with buckbean (20% cover), water hemlock (10%), marsh fivefinger (5%) and water sedge (5%) with a water depth over the mat of 12 cm (3.3 in.), the mat deflection was 20.3 cm (4.5 in.).

### Surface flow

Water moves slowly through these fens from south-east to northwest (toward the Tanana River), with the rate generally increasing "downstream," or closer to the river. In some fens farther inland, no flow could be detected. Flow rates of water standing above the floating mats or in openings in the mats were only 5 cm/s. Where airboats had cleared the above-water vegetation, surface flow was up to 11 cm/s. The locations controlling the outflow of water from these wetlands into the Tanana River are poorly defined, although at least two outlet streams were identified. The control and origin of water levels in the flats is not known; however, water levels have been generally reported as high over the past few years, even though interior Alaska has experienced

**Table 2. Characteristics of the water chemistry of wetlands in the Tanana Flats compared with literature-based values for a bog north of the Tanana River in the Yukon–Tanana uplands.**

| Characteristic          | Floating<br>mat fen in<br>Tanana Flats | Bog on<br>north side of<br>Tanana River* |
|-------------------------|--|--|
| pH                      | 7.2 (0.2) <sup>†</sup>                 | 4.0                                      |
| Conductivity (µmhos/cm) | 329 (44)                               | 31.0                                     |
| Calcium (mg/L)          | 43.7 (6.8)                             | 2.0                                      |
| Magnesium (mg/L)        | 8.8 (1.5)                              | 0.1                                      |
| Movement (cm/s)         | 5–16                                   | 0.0                                      |
| Source                  | Groundwater                            | Precipitation                            |

\* Data from Luken and Billings (1983).

<sup>†</sup> Mean (standard deviation); n = 6.

a warming and drying trend. Water levels were much higher in late August 1990 than at the same time in 1989. Surface water temperatures were relatively high (12–18°C) in late August 1989 and 1990.

### Water chemistry

The surface water collected at six fen sites was slightly alkaline (pH = 7.2) and had relatively high conductivities ranging from 270 to 400 µmhos/cm (Table 2). Calcium and magnesium levels averaged 48 and 9 mg/L, respectively. Wood River water samples reported by the Hydrographic Topographic Center (1978) indicate conductivities similar to those presented here.

### Permafrost

The water depth beneath the floating mats was greater than 2 m (the length of our probe); therefore, it was not possible to determine if permafrost was present beneath these fens. However, on several slightly higher (0.5- to 2-m relief) forested areas bordering these fens, frozen ground was measured at a depth of about 50 cm in early September 1989. The soil profile consisted of thick organic peat above the frozen ground. Near the edge of these "uplands" where they slope down to meet the wetland, the depth to the frozen layer increased to 1 m. A short distance out into the water of the fen, no frozen ground could be found at the maximum probe depth of 2 m. We therefore assume that permafrost is very deep or absent under the floating marsh wetlands. In addition, along this same boundary between the fen and forested upland, there is frequent evidence of permafrost thaw and subsidence (Fig. 3). Dead and falling birch trees are particularly conspicuous, and the white trunks of standing dead birch trees often protrude from the marsh area.



*Figure 3. Floating fen wetland showing an airboat trail and a border of dead and dying birch and spruce along the boundary between the wetlands and forested upland islands and benches. Note the dead trunks of paper birch protruding from the wetland mat at the bottom of the photo.*

The permafrost dynamics in the Tanana Flats is probably similar to that just across the Tanana River in the Fairbanks area. Péwé and Reger (1983) indicated that the permafrost in this area is as much as 81 m thick, but unfrozen areas typically exist beneath river channels, lakes and sloughs. As noted earlier, the variable nature of the sediments in the Tanana Flats is important in permafrost distribution. Better-drained gravel layers tend to be unfrozen, whereas poorly drained sand and silt beds are often frozen. Coupled with the fact that these sediments occur on the alluvial toeslope of a large coalesced fan complex, both surface and subsurface water movement undoubtedly play a part in determining frozen ground distribution.

## DISCUSSION AND CONCLUSIONS

Several lines of evidence support the hypothesis that the floating fens described here are ground water-discharge wetlands fed by springs that upwell through "holes," or unfrozen areas in the discontinuous permafrost, in the northwest corner of the Tanana Flats.

1. Permafrost is present on the raised forested benches and islands bordering the fens but appears to be absent under the wetlands. Figure 4 shows in

profile how subpermafrost groundwater moving downslope from the Alaska Range could reach the surface where the gradient flattens and where there are gaps in the permafrost under the wetlands. The permafrost matrix in which these floating fens occur could act as a confining bed and create artesian conditions for the discharge of groundwater to produce spring-fed wetlands (Williams 1970).

2. Areas of winter icings (unfrozen water discharge) have been detected in the Tanana Flats by Collins and Haugen (1990) using infrared thermal remote sensing techniques. Such icings probably are areas where groundwater springs remain unfrozen during the winter. Although this winter study was conducted to the east of the present wetlands study, the results confirm the importance of groundwater discharge in the Tanana Flats and support the scheme pictured in Figure 4.
3. The composition and structure of the vegetation in the floating fens of the Tanana Flats, and in particular the complete absence of *Sphagnum*, are similar to groundwater-discharge areas described by Koerselman et al. (1990) in the Netherlands. The same species that dominate the Tanana Flats fens also characterize these European groundwa-

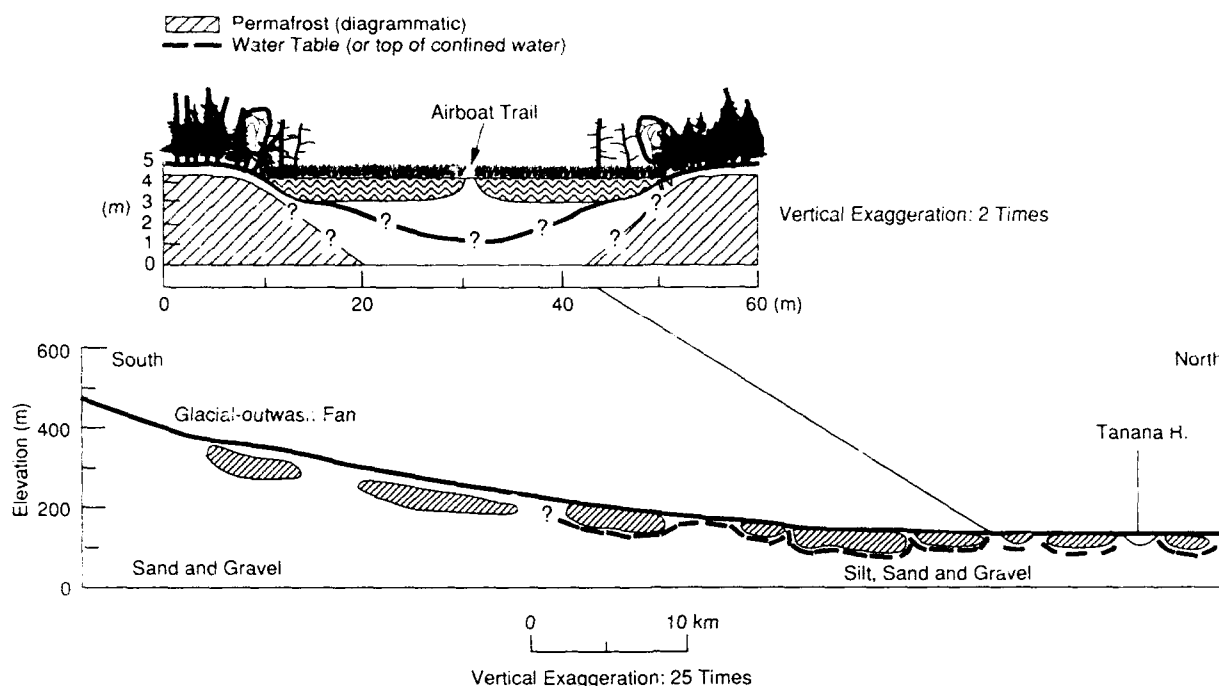


Figure 4. Cross section from the Alaska Range to the Tanana River, showing the hypothetical distribution of permafrost and movement of groundwater in relation to its discharge and the formation of floating fen wetlands in the Tanana Flats. [Based on field observations and information from Hopkins et al. (1955) and Péwé and Bell (1975).]

ter-discharge areas, including *Menyanthes trifoliata*, *Potentilla palustris* and *Equisetum fluviatile*.

4. The relatively high pH, conductivity and calcium and magnesium concentrations of the water, together with their nutrient levels and temperatures, suggest groundwater and spring sources. Such minerotrophic wetlands or fens are indicative of areas receiving flowing or percolating groundwater (Heinselman 1963). The nutrient levels, pH and vegetation of these Tanana Flats wetlands contrast sharply with the predominantly acid and nutrient-poor bogs and muskegs in most other interior Alaska lowland areas and those nearby on the north side of the Tanana River (Luken and Billings 1983) (Table 2).

These floating fens appear to be expanding in some areas of the Tanana Flats as a result of permafrost thaw and subsidence along the boundary between the wetlands and the forested uplands (Fig. 3 and 4). This thermokarst development suggests a dynamic process of heat transfer from the relatively warm wetland water to the permafrost, with subsequent melting and subsidence of the upland surface. The circulating groundwater

in these wetlands could also degrade the permafrost. Likens and Johnson (1968) showed high rates of heat flow from the water of lakes into the surrounding terrain in the Tanana drainage east of the present study area. Because the mean annual temperature in Fairbanks is only 2–3°C below freezing, and the temperature of permafrost in this area at a depth below the level of seasonal temperature fluctuations (8–15 m) is about –0.5°C (Pewé and Reger 1983), the relatively “warm” sensitive permafrost may be susceptible to such thermal degradation. Higher temperatures in interior Alaska during the past ten years (Osterkamp 1983) may have increased the rate of wetland expansion.

The forested upland islands could theoretically expand through a rising of the permafrost table and an accompanying rise in the peat above the water level of the surrounding wetland. The improved drainage would allow trees to become established, and the forested island would expand.

A floating mat, or *schwingmoor*, structure (Moore and Bellamy 1974) is a well-accepted phenomenon, but it is usually associated with peatlands and *Sphagnum* moss found near the edge of open-water ponds, where it represents a late stage in peat-filling. Ovenden and

Brassard (1989) described such areas in the Old Crow Flats. Floating peat mat development has been described in more southern kettle hole or ice-block depression areas, where a deep, steep-sided basin allows horizontal mat growth to exceed vertical peat accumulation (Wilcox and Simonin 1988). Probing with a 2-m soil corer along the edge of the Tanana Flats wetlands suggests a steep-sided basin, but we do not know the geologic origin of these basins. Other descriptions of interior Alaskan lowland vegetation dominated by peat and Sphagnum moss are provided by Drury (1956) for the Kuskokwim River-Nixon Flats lowlands, Delapp\* and Talbot and Markon (1988) for the Innoko Lowlands, Talbot et al. (1985) for the Kanuti Flats and Johnson and Vogel (1968) in the Yukon Flats. Occasionally these authors described fens, similar to those found in our study area, restricted to lake edges, shores and oxbow lakes that receive periodic inputs of silt. The floating mat wetlands of the Tanana Flats appear to be more closely related to tropical floating mats composed of vascular macrophytes (Junk 1983) than to the moss and peat mats usually composing northern *schwingmoor*.

\*Personal communication.

## LITERATURE CITED

- Abele, G., L.A. Johnson, C.M. Collins and R.A. Taylor (1978) Effects of winter military operations on cold regions terrains. USA Cold Regions Research and Engineering Laboratory, Special Report 78-17.
- Anderson, G.S. (1970) Hydrological reconnaissance of the Tanana Basin, central Alaska. U.S. Geological Survey, Hydrological Investigations Atlas HA-319.
- Collins, C.M. and R.K. Haugen (1990) Thermal infrared survey of winter trails in the Ft. Wainwright Training Area, Alaska. USA Cold Regions Research and Engineering Laboratory, Special Report 90-17.
- Doe, W.W., C. Collins, J. Brown, R. Kreig, R. Haugen and B. Bailey (1985) Mapping of terrain and environmental attributes, Blair Lakes, Ft. Wainwright Training Area, Alaska. CRREL contract report to DEH, 6th Light Infantry Division, Fort Richardson, Alaska.
- Drury, W.H., Jr. (1956) Bog flats and physiographic processes in the Upper Kuskokwim River region, Alaska. *Contributions of the Gray Herbarium*, 178.
- Ford, J. and B. L. Bedford (1987) The hydrology of Alaskan wetlands, U.S.A.: A review. *Arctic and Alpine Research*, 19: 209-229.
- Gabriel, H.W. and S.S. Talbot (1984) Glossary of landscape and vegetation ecology for Alaska. U.S.D.I. Bureau of Land Management, Alaska, Technical Report 10.
- Haugen, R.K., C.W. Slaughter, K.E. Howe and S.L. Dingman (1982) Hydrology and climatology of the Caribou Poker Creek Watershed, Alaska. USA Cold Regions Research and Engineering Laboratory, CRREL Report 82-26.
- Heinselman, M.L. (1963) Forest sites, bog processes and peatland types in the glacial Lake Agassiz region, Minnesota. *Ecological Monographs*, 33: 327-374.
- Hopkins, D.M., T.N.V. Karlstrom, R.F. Black, J.R. Williams, T.L. Péwé, A.T. Fernald and E.H. Muller (1955) Permafrost and ground water in Alaska. U.S. Geological Survey, Professional Paper 264-F, p. 113-114.
- Hydrographic Topographic Center (1978) Ft. Wainwright terrain analysis. USA Engineer Topographic Laboratory, Fort Belvoir, Virginia.
- Johnson, P.L. and T.C. Vogel (1966) Vegetation of the Yukon Flats region, Alaska. USA Cold Regions Research and Engineering Laboratory, Research Report 209.
- Junk, W.J. (1983) Ecology of swamps on the Middle Amazon. In *Ecosystems of the World. 4B. Mires: Swamp, Bog, Fen and Moor* (A.J.P. Gore, Ed.). New York: Elsevier, p. 269-294.
- Koerselman, W., S.A. Bakker and M. Blom (1990) Nitrogen, phosphorus and potassium budgets for two small fens surrounded by heavily fertilized pastures. *Journal of Ecology*, 78: 428-442.
- Lensink, C.J. and D.V. Derksen (1986) Evaluation of Alaskan wetlands for waterfowl. In *Alaska: Regional Wetland Functions. Proceedings of a Workshop, May 28-29, 1986*, p. 45-76.
- Likens, G.E. and P.L. Johnson (1968) A limnological reconnaissance in interior Alaska. USA Cold Regions Research and Engineering Laboratory, Research Report 239.
- Luken, J.O. and W.D. Billings (1983) Changes in bryophyte production associated with a thermokarst erosion cycle in a subarctic bog. *Lindbergia*, 9: 163-168.
- Moore, P.D. and D.J. Bellamy (1974) *Peatlands*. New York: Springer-Verlag.
- Osterkamp, T.E. (1983) Response of Alaskan permafrost to climate. In *Proceedings of the Fourth International Conference on Permafrost, Fairbanks, Alaska*. National Academy Press, Washington, D.C., p. 145-152.
- Ovenden, L. and G.R. Brassard (1989) Wetland vegetation near Old Crow, northern Yukon. *Canadian Journal of Botany*, 67: 954-960.
- Péwé, T.L. (1975) Quaternary geology of Alaska. U.S. Geological Survey, Professional Paper 835.
- Péwé, T.L. and J.W. Bell (1975) Map showing ground water conditions in the Fairbanks D-2 SE Quadrangle, Alaska. U.S. Geological Survey, Map MF-669B.
- Péwé, T.L. and R.D. Reger (1983) Middle Tanana River

Valley. In *Guidebook 1: Richardson and Glenn Highways, Alaska* (T.L. Péwé and R.D. Reger, Ed.). Fourth International Conference on Permafrost, Alaska Division of Geological and Geophysical Surveys, Fairbanks, p. 5-45.

**Talbot, S., M.D. Fleming and C.J. Markon** (1985) Landsat-facilitated vegetation map and vegetation reconnaissance of Kanuti National Wildlife Refuge, Alaska. U.S. Fish and Wildlife Service, Resource Support, Anchorage, Alaska.

**Talbot, S.S. and C.J. Markon** (1988) Intermediate-scale vegetation mapping of Innoko National Wildlife

Refuge, Alaska, using Landsat MSS digital data. *Photographic Engineering and Remote Sensing*, **54**: 377-383.

**Van Cleve, K., F.S. Chapin, III, P.W. Flanagan, L.A. Viereck and C.T. Dyrness** (Ed.) (1986) *Forest Ecosystems in the Alaskan Taiga. A Synthesis of Structure and Function*. New York: Springer-Verlag.

**Wilcox, D.A. and H.A. Simonin** (1988) The stratigraphy and development of a floating peatland, Pinhook Bog, Indiana. *Wetlands*, **8**: 75-91.

**Williams, J.R.** (1970) Groundwater in the permafrost regions of Alaska. U.S. Geological Survey, Professional Paper 696.

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